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"Should you really chat while reading?" effects of on-screen multitasking and text disfluency on integrated understanding

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ABSTRACT

Students' multitasking during lectures or academic assignments is a common activity that may have negative effects on performance. It is therefore relevant to investigate under what conditions such negative effects can be reduced. The current study brought together two separate lines of research to examine the effects of on-screen multitasking and text disfluency. Multitasking required students to read and respond to social media messages during reading. Text disfluency was perceptual in the form of harder-to-read versus easy-to-read text. We included 208 university students, who were randomly assigned to one of the four conditions resulting from a 2 x 2 between-subjects design. Participants read two dual-positional texts on sun exposure and health. Dependent on the assigned condition, they could read perceptually fluent or disfluent texts, and they could intermittently receive, or not receive, on-screen social media messages while reading. As outcome variables, we measured participants' perception of cognitive load, integrated text understanding, and metacognitive calibration of text understanding. We also controlled the possible contributions of the individual differences of prior knowledge, reading comprehension skills, working memory, and cognitive flexibility. Results showed a negative effect of multitasking on the integrated understanding of the dual positional texts with non-multitaskers outperforming multitaskers. Perception of cognitive load and metacognitive calibration were not affected by multitasking. No impact of disfluency was observed for any of the outcome variables, and the interactive effect of multitasking and disfluency was also not statistically significant. Limitations and directions for future research are discussed.

1. Introduction

Today's students read assigned learning materials on digital devices that are permanently connected to the Internet. A typical context of reading to learn is characterized by media multitasking (Dönmez & Akbulut, 2021; Luo et al., 2020; Ophir et al., 2009), as students often engage in a secondary task, for example when responding to messages from social media. As our attentional and working memory capacities are limited, disruption during reading may have negative effects on text processing and comprehension (Hong

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et al., 2004; Liu & Gu, 2020), although some studies have not found any impact of multitasking (e.g., Fante et al., 2013; Tran et al., 2013). By means of meta-analyses, research has documented that digital reading *per se* leads to lower expository text comprehension compared to reading in print (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018; Salmerón et al., 2024), possibly due to a more superficial approach that characterizes quick and immediately rewarding interactions with digital devices (Annisette & Lafreniere, 2017). The Clinton (2019) meta-analysis also indicated that metacognitive calibration, that is, the absolute accuracy of readers' self-judgment of comprehension compared to their actual comprehension performance (e.g., Metcalfee, 2002), was lower when reading digitally. Meta-analytic research has also indicated that multitasking negatively affects text comprehension, in particular when reading time is limited (Clinton-Lisell, 2021). Further, reported multitasking during a college lecture has been shown to be negatively related to students' memory for the lecture's content (Jamet et al., 2020), in particular among students who used their laptop to take notes. Similarly, multitasking while watching an instructional video reduced undergraduates' learning gains compared to a control condition (Dönmez & Akbulut, 2021). Multitasking was also found to be associated with lower academic performance (le Roux et al., 2021). It is therefore both theoretically and practically relevant to investigate what might mitigate the effects of media multitasking when reading digitally.

In that regard, we took research within *disfluency theory* into consideration. Making information harder to process perceptually may lead to more effortful and analytical processing due to an increase in the perception of difficulty (Alter et al., 2007). That is, a text that is slightly more difficulty to read due to its font type and color can cue a deeper processing of the learning content (Diemand-Yauman et al., 2011; French et al., 2013; Halin, 2016; Halin et al., 2014; Sungkhasettee et al., 2011). A disfluent (harder-to-read) text may introduce a 'desirable difficulty' (Bjork, 2013), which is considered to promote self-regulated learning, in this case by signaling readers that they may not master the text content without deeper information processing.

To advance current knowledge we brought together two separate lines of research, that is, research on multitasking and research on disfluency. We were interested in possible ways to mitigate the potential negative impact of multitasking while reading learning materials. Thus, we investigated perceptual disfluency in relation to a multitasking context. We did not regard disfluency as educationally relevant in and of itself, that is, as an 'ordinary' condition for learning, but as one possible way to counteract the potentially negative effects of multitasking. Therefore, we explored the possible interactive effect of the two factors on multiple dependent reading outcomes, specifically on the perception of cognitive load, integrated understanding, and metacognitive calibration. In the next sections, we provide a theoretical background focusing on the constructs of on-screen multitasking and disfluency during reading and learning from text. We then describe the unique characteristics of the present study, including the research questions and hypotheses that directed our investigation.

1.1. On-screen multitasking and effects on reading outcomes

Multitasking is defined as the simultaneous carrying out of two or more information processing tasks (Kirschner & Karpinski, 2010; Ophir et al., 2009). The multitasking phenomenon did not start with the use of digital reading devices. Readers can engage in a secondary task, for example watching TV while reading printed materials, but during digital reading the number of potential media 'attractions' and distractions can be larger because the reading devices are permanently connected to the Internet. Thus, digital reading may result in a fragmented and confused activity (Liu & Gu, 2020). The practice of on-screen multitasking is of particular concern in educational contexts as it necessarily diverts students from the reading activity, with likely negative consequences for comprehension performance (Clinton-Lisell, 2021).

Within the extant literature on the effects of multitasking on reading, one line of research investigates the phenomenon at a 'distal' level, that is, the relationships between a habitual tendency to engage in other media use while reading and reading outcomes. The findings from correlational designs indicate that stronger multitasking habits are associated with poorer reading comprehension performance (Cain et al., 2016; Chevet et al., 2022; Romero et al., 2023). For example, Romero et al. (2023) recently found that undergraduates' comprehension of two lengthy texts was negatively associated with their multitasking reading habits after controlling for relevant individual differences such as prior knowledge and reading comprehension skills. Other correlational studies have documented a negative link between multitasking (e.g., texting) during lectures and students' academic performance (e.g., Bellur et al., 2015; Jamet et al., 2020; Junco & Cotton, 2012; Sana, Weston, & Cepeda, 2013).

Another line of research, more pertinent to the current study, adopts a 'proximal' level of analysis, that is, uses experimental designs in which multitasking occurs while students read some materials and may detract from the completion of reading assignments. Readers engage in multitasking either by reading only short messages from social media or by performing a more demanding secondary task during reading. To provide a complete review of such investigations is not within the scope of this article, as we focus on on-screen multitasking that occurs when students are reading provided learning material and simultaneously engage with on-screen stimuli that appear abruptly. That is, students are still reading during multitasking, but the secondary reading activity is incompatible with the primary reading task that has a different goal (Lin & Bigenho, 2015). In the following, we review some of the most pertinent studies as examples of investigations with different on-screen stimuli that involve university students.

When focusing on the reading of simple ads and short messages from social media, which appeared on left and right sides of the screen, Ronconi, Mason, Manzione, and Schüler (2024) did not find any impact of multitasking on university students' text comprehension. Even when college students were also required to respond to instant messages and their multitasking was examined in relation to the level of difficulty of the reading task, Fante et al. (2013) did not find any effect of distractions on text comprehension, although the reading process was less efficient. Similar results were indicated by Bowman et al. (2010) as participants needed longer time to reach the same level of text comprehension when engaging in instant messaging during reading. Tran et al. (2013) investigated the effects of responding to social messages concurrently or sequentially when reading, finding no effects of concurrent multitasking on text comprehension. The lack of a multitasking effect was corroborated in two other studies in which Tran et al. (2013) manipulated the intrinsic cognitive load of the primary reading task and the extent to which the distracting task stimulated a deeper conversational discourse.

However, there are also contrasting findings in the literature. For instance, Lin et al. (2011) showed university students a video about news or a comedy simultaneous with the reading task. In one condition, the video could be ignored as it appeared on the background, whereas in the other condition, it could not be ignored as readers were told that they would respond to questions after the video. It was observed that the comedy video led to poorer text comprehension regardless of the particular multitasking condition, whereas the news video negatively influenced comprehension only in the active multitasking condition. In the context of multiple-text comprehension, Haverkamp et al. (2024) examined the effects of multitasking in the form of receiving and reading short social messages on a smartphone while reading four partly conflicting texts on the topic of sun exposure and health. After reading each paragraph of the texts, undergraduates were asked either to summarize the main idea of the paragraph in writing or to reread the paragraph. Participants' were assessed with respect to their reported use of cross-text elaboration strategies and their integrated understanding of the four texts. Results showed that multitasking on the phone negatively affected integrative processing and comprehension, with summarizing mitigating the detrimental effects of multitasking. However, integrative processing was not found to mediate the effect of multitasking on integrated understanding.

In sum, the results concerning the effects of on-screen multitasking on text comprehension remain inconclusive. As mentioned above, the Clinton-Lisell (2021) meta-analysis indicated an overall negative impact of multitasking. It should be noted, however, that this meta-analytic study also reviewed investigations in which multitasking occurred during reading on paper and, interestingly, found that the detrimental effect was greater when reading in print than when reading on screen. Further research is therefore needed to better understand the effects of multitasking during digital reading.

Text understanding is not the only outcome of the reading process. The perception of cognitive load is also an important outcome of reading learning materials, potentially influencing, for instance, readers' task persistence (Feldon et al., 2019). In the context of multitasking, perception of cognitive load has so far received little attention, yet seems relevant. As we will explain in the next section, if limited working memory capacity is overtaxed because a secondary task is carried out while performing the primary reading task, the perception of cognitive load likely increases. In this regard, Örün and Akbulut (2019) found that concurrent multitasking resulted in higher perceived cognitive load and poorer information retention, especially when multitaskers were learning in a cafeteria. However, more recently, no significant differences between multitaskers and no-multitaskers with respect to the perception of cognitive load were found in a lab study in which multitaskers read multiple short social media messages while reading complex science texts (Ronconi et al., 2024).

Further, another outcome of text reading is subjective judgment of understanding or metacognitive calibration, that is, the accuracy of students' self-evaluation of their understanding. The effect of multitasking on metacognitive calibration is also an issue worth investigating, given the relevance of self-judgments for self-regulated learning (e.g., Rutherford, 2017). Peng and Tullis (2021) did not find any statistically significant differences between a multitasking condition in which participants responded to auditory stimuli and a non-multitasking condition with respect to monitoring accuracy when reading word lists. A recent study by Romero et al. (2023), however, showed that habitual multitasking was associated with lower metacomprehension accuracy. Another recent study by Guo et al. (2024) found that multitasking occurring while reading word pairs impaired metacognitive monitoring in both artificial and real-life simulated scenarios.

1.2. Why is multitasking detrimental?

The processing of learning material requires top-down and goal-directed attention to stay focused and inhibit distractions (e.g., Parker, 2022). Given the limiting architecture of the human mind, simultaneous execution of cognitive activities leaves less resources available for each activity. In the following, we briefly refer to theoretical accounts that can provide explanations for the cognitive cost of multitasking with respect to text comprehension. Among them is the *theory of cognitive load*, which posits that when working memory (WM) becomes overloaded, cognitive functioning necessarily decreases (Sweller, 1994; Sweller et al., 2011). During the reading of a text, for instance, efficient WM is needed to process the content, which is integrated with our prior knowledge and transferred to long-term memory. Engaging in a secondary task while performing a primary reading task, likely impairs the processing of the content to be learned due to cognitive overload and limited WM capacity. In fact, learning materials should be created taking into account the need to reduce cognitive load that does not serve learning, termed extraneous cognitive load within cognitive load theory. According to this theory (Sweller et al., 2011), on-screen extraneous stimuli or distractions (e.g., social media messages) leading to multitasking while performing a primary reading task will increase extraneous cognitive load and, consequently, is also likely to increase the subjective perception of cognitive load (Örün & Akbulut, 2019).

Developed within the framework of the ACT-R cognitive architecture (Anderson, 2007), *threaded cognition* is another theory that explains the mechanism underlying the interference of multitasking. According to this theory, multiple active tasks need to be processed serially, not simultaneously, when they draw on the same kind of cognitive, perceptual, or motor resources (Salvucci &Taatgen, 2008; 2011). Th is implies that human cognition can have full access to the relevant resources for a new processing thread only when the previous thread is completed. In other words, when a processing thread is active, a new one must stand in queue until the previous one is finished. Multiple threads can be active concurrently only to the extent that they do not overlap with respect to the cognitive resources they use. A clear implication can be drawn from the theory of threaded cognition. When students are reading for an academic assignment and then start reading and responding to social messages, they engage in a secondary task that is incompatible with the primary task with respect to the reading goal, but still overlaps with the primary task in terms of the cognitive resources it draws on.

According to the theory, the architecture of their minds allows them to use resources for the secondary task, but they cannot think about the primary task concurrently and, as a consequence, deeper comprehension of academic materials will be impaired (Haverkamp et al., 2024). Of note is that when students return to the primary task, it may still be subject to interference from the non-compatible secondary task, which may be considered a “hidden cost of intermittent multitasking” (Strayer et al., 2022).

Yet another, more recent theoretical account of media multitasking is the *exploitation-exploration model* by Wiradhany et al. (2021). Exploitation refers to a situation in which engagement in the primary task can begin to fade. Exploration concerns the increased appeal of alternative tasks in that situation. Whereas exploitation behavior implies engagement in a task in which effort can be rewarded, engagement will decrease when rewarding becomes too low and the task cost too high, with exploration behavior taking over. Both exploitation and exploration are triggered by internal (e.g., the emotion of boredom) and external (e.g., affordances of digital devices) cues. A balance between the two kinds of behavior is important for adaptation. Individual differences are considered to impact the tradeoff between exploitation and exploration because people are more or less able to deeply engage in the task at hand or inclined to shift to another. According to Wiradhany et al. (2021), negative effects of multitasking may be observed among individuals who do not benefit optimally from engaging in the primary task and instead do random exploration, especially when they are less experienced and not able to use efficient strategies in shifting between exploitation and exploration. Importantly, despite their divergences, the theoretical accounts we reviewed share the concern that multitasking may have a cost for cognitive performance.

1.3. Disfluency and effects on reading outcomes

In seeking to counteract the tendency toward superficial and quick processing of learning material during digital reading that likely occurs in a multitasking context, we took research within *disfluency theory* into account. According to this theory, making information harder to process perceptually may lead to more effortful and analytical processing due to an increase in the perception of difficulty (Alter, 2007). Specifically, a disfluent text that is slightly more difficult to read due to its font type and size can cue a deeper processing of the learning content by facilitating selective attention and cocued engagement with the task (Diemand-Yauman et al., 2011; French et al., 2013; Halin, 2016; Halin et al., 2014; Sungkhasettee et al., 2011). A disfluent, harder-to-read text may introduce a ‘desirable difficulty’ (Bjork, 2013), which is considered to promote self-regulated learning, signaling to readers that they may not master the text content without deeper information processing.

However, research findings on disfluency are mixed (Kühl & Eitel, 2016). There are studies documenting a benefit of reading disfluent texts, such as the Halin et al. (2014) study, which is particular relevant to our investigation as it manipulated two variables, disfluency and the physical reading condition. Participants read two texts in fluent and disfluent versions in two different physical reading conditions, one more favorable than the other: a quiet condition and a condition with background speech noise (i.e., a 2 x 2 design). An interesting interaction was observed: recall of text content was poorer in the noisy condition but only when the texts were also easy to read (i.e., fluent). That is, disfluency seemed to compensate for the unfavorable, more noisy reading condition. Interestingly, best recall was observed when speech noise background was combined with disfluent texts. In another related study that is also relevant to the current investigation, disfluency was examined in relation to a silent condition and three different sound conditions: background speech, aircraft noise, and road traffic noise (Halin, 2016). Participants had poorer post-reading performance on a multiple-choice test in all three sound conditions when reading easy-to-read texts. However, when participants read harder-to-read texts, no differences emerged for their performance across the experimental conditions. The authors considered disfluency as a ‘shield’ against distraction in unfavorable environmental conditions (Halin, 2016; Halin et al., 2014).

There are also studies that do not show any positive effect of disfluent material (e.g., Eitel et al., 2014, 2016),or even a negative effect (Yue et al., 2013). For instance, in a series of four multimedia experiments in which college students learned from easy-to-read and harder-to-read texts and pictures, the disfluency effect only emerged in the first experiment favoring transfer of learning and deeper effort, but these findings were not corroborated by the following experiments reported by Eitel et al. (2014).

Lehmann, Goussios, and Seufert (2016) showed a moderating role of working memory when university students read a disfluent or a fluent text. Specifically, the disfluent text was advantageous for retention and comprehension only for those with higher working memory. In contrast, those with lower working memory performed better after reading the fluent text, suggesting that deeper processing to counteract the greater demand imposed by reading a harder-to-read text only may occur at a certain level of working memory.

Disfluency can also impact the perception of cognitive load. Alter et al. (2007) posited that presenting difficulties can support deeper processing because the perceived, but not necessarily the objective, difficulty associated with the task increases. This perception promotes the investment of mental effort and analytical processing. However, research has either documented an increase in cognitive load due to text disfluency (Eitel et al., 2014, exp. 1) or showed no effects of disfluency (Eitel et al., 2014, exp. 2, 3, and 4), suggesting that disfluency might interact with other aspects of the task in causing perceptions of higher load.

Regarding the impact of perceptual fluency, some studies examined metacognitive calibration in terms of the accuracy of self-judgment when compared with actual performance. For instance, Yue et al. (2013) asked participants to memorize lists of words written in a clear and a blurred font. A series of experiments using a within-subjects design showed that judgments of learning were consistently higher for fluent fonts and, in turn, related to performance. However, with a between-subjects design, no differences related to perceptual fluency were observed, suggesting that disfluency can promote deeper processing by creating a desirable difficulty during reading, but only under certain conditions. A series of studies by Magreehan, Serra, Schwartz, and Narciss (2016) did also not show any impact of disfluency on judgments of learning during the learning of word lists. It should be noted, however, that Yue et al. (2013), Magreehan et al. (2016) used word lists as learning materials. For longer and more demanding informational texts, the effect of perceptual disfluency could be either more or less evident, however.

In sum, fluency may have some potential for promoting effortful processing under certain conditions and in combination with individual characteristics that make difficulty really desirable (Bjork & Yue, 2016; Dunlosky & Mueller, 2016). To our knowledge, no research on disfluency has been conducted in a multitasking reading context in which effortful and elaborative processing is crucial for deeper comprehension. The effects of both multitasking and disfluency on text comprehension are thus an area well worth investigating.

1.4. The current study

This study is a unique extension of prior research on both on-screen multitasking and text disfluency. We were particularly interested in the unexplored interactive effect of the two variables. On the one hand, according to some of the reviewed literature, multitasking while reading learning materials has a negative impact on cognitive load (Örün & Akbulut, 2019), text understanding (e.g., Haverkamp et al., 2024; Lin et al., 2011), and metacognitive calibration of understanding (Romero et al., 2023). On the other hand, according to other reviewed literature, disfluency has a positive impact on text understanding (e.g., French et al., 2013; Halin, 2016; Halin et al., 2014) and metacognitive calibration of understanding. It therefore seems theoretically and practically valuable to investigate whether perceptual disfluency may counteract the negative influence of multitasking by signaling that a harder-to-read text requires deeper information processing in order to be understood. Taking into account that students tend to approach digital texts in a more superficial way than printed texts (Annisette & Lafreniere, 2017), as also indicated by eye-tracking research (Jensen et al., 2024), and that a multitasking context may impair content processing because attention is detracted from the primary reading task, we wanted to explore if disfluency could compensate for an unfavorable condition in which two incompatible reading tasks are performed simultaneously (Salvucci & Taatgen, 2008). In essence, the potentially mitigating role of disfluency, which signals difficulty, rests on promoting a more effortful and analytical approach to text reading. To some extent, we were inspired by Halin (2016) and Halin et al.s' (2014) investigations of disfluency in relation to unfavorable reading conditions involving distracting noises, with multitasking corresponding to a distracting and disturbing context for reading learning materials.

We focused on dual-positional texts that presented partially conflicting perspectives on a topic because understanding and metacognitive calibration of understanding can be considered more demanding with such texts compared to single-positional texts. Constructing meaning from a dual-positional text requires that readers represent similarities and differences between two points of view within an integrated situation model (Kardash & Howell, 2000). Metacognitive monitoring of understanding is also more demanding with dual-positional than with single-positional text (List & Lin, 2023). Presumably, integrated understanding and self-evaluation of understanding may be even more demanding in a multitasking context (List & Lin, 2023). Thus, it seems reasonable to assume that performing a secondary task while reading to understand a dual-positional text could negatively interfere with the outcomes of the reading process.

Three research questions guided the study.

(1) Do multitasking and disfluency independently and interactively affect the perception of cognitive load?
(2) Do multitasking and disfluency independently and interactively affect the integrated understanding of dual-positional texts?
(3) Do multitasking and disfluency independently and interactively affect metacognitive calibration of text understanding?

Based on theoretical perspectives and mixed empirical results reviewed in the previous sections about the two separate lines of investigation concerning multitasking and disfluency, we formulated two different working hypotheses for each research question. Specifically, according to *Hypothesis 1a*, neither multitasking (Ronconi et al., 2024) nor disfluency (Eitel et al., 2014, exp. 2, 3, and 4) would have any independent effect on the perception of cognitive load. That is, the two manipulated variables would not lead to a subjective impression of higher load on working memory, which means that the second concurrent reading task and the harder-to-read font were not perceived as imposing extraneous cognitive load on students. In contrast, according to *Hypothesis 1b*, both multitasking (Örün & Akbulut, 2019) and disfluency (Eitel et al., 2014, exp. 1) would have an independent negative impact on the perception of cognitive load (Sweller, 1994). Specifically, both variables would contribute to a subjective impression of overloaded working memory: multitasking because two tasks are carried out simultaneously (Örün & Akbulut, 2019) and disfluency because a harder-to-read font type is perceived as imposing extraneous load during reading, even when this is not actually the case (Alter et al., 2007).

According to *Hypothesis 2a*, neither multitasking (e.g., Fante et al., 2013; Tran et al., 2013) nor disfluency (Eitel et al., 2014; Eitel & Kühl, 2016) would have any independent effect on text understanding. That is, text understanding would not be significantly impaired despite a potentially interfering reading task and a perceptually disfluent text. In contrast, according to *Hypothesis 2b*, both multitasking (e.g., Haverkamp et al., 2024; Lin et al., 2011) and disfluency (Diemand-Yauman, Oppenheimer, & Vaughan, 2011; Eitel et al., 2014, exp. 1) would have an independent impact on text understanding. Specifically, multitasking would lead to poorer understanding of the learning materials because it impairs content processing (Salvucci & Taatgen, 2011; Sweller et al., 2011). However, disfluency would lead to deeper processing by signaling a need for engagement with the text in a situation characterized by 'desirable difficulty' (Bjork, 2013), thus facilitating understanding.

Finally, according to *Hypothesis 3a*, neither multitasking (Peng & Tullis, 2021) nor disfluency (Mueller et al., 2014) would have any independent effect on metacognitive calibration. In contrast, according to *Hypothesis 3b*, both multitasking (Guo et al., 2024; Romero et al., 2023) and disfluency (Magreehan et al., 2016; Yue et al., 2013) would have an independent impact on metacognitive calibration. Specifically, multitasking would impair metacognitive judgments of understanding because it becomes even more difficult to monitor understanding with the limited resources available for meta-level processing in a situation where significant resources are directed to the object-level (Guo et al., 2024). However, disfluency can benefit not only understanding but also the subjective metacognitive evaluation of understanding by signaling a need for deeper engagement with the text (Dunlosky & Mueller, 2016).

As pointed out, research on multitasking and research on disfluency are two separate areas in the literature and the possibility of interactive effects has not been addressed in previous investigations. Yet, it seems relevant to examine the role of disfluency in relation to multitasking because possible interactive effects might have implications for both theory building and practice. Accordingly, Halin (2016) and Halin et al. (2014) also investigated the interaction between disfluency and another potentially distracting variable, the physical condition of reading (i.e., quiet vs. noisy, and quiet vs. different levels of noise), as previously reviewed.

We therefore took an exploratory approach by investigating possible interactions between the two factors based on extant literature. As already argued, taking the potentially positive effects of disfluency into account raises the intriguing possibility of an interaction involving that disfluency counteracts a quick and superficial approach to text processing because the perceptual difficulty of the text is considered to require a more effortful approach, thus sustaining text understanding and self-judgment of understanding even in a multitasking condition with higher cognitive load.

In pursuing our aims, we also took the role of relevant individual differences into account. Specifically, we considered participants' prior knowledge, reading comprehension skills, working memory, and cognitive flexibility, which could influence the outcome variables as documented in previous research (e.g., Butterfuss & Kendeou, 2017; Cain, 2016; Haverkamp et al., 2024; Mason et al., 2022; Ronconi et al., 2022; Zaccoletti et al., 2020). Although the reasons for taking the first three individual differences into account seem quite evident, a justification may be needed for cognitive flexibility or shifting. Cognitive flexibility is one of the three executive functions included in Miyake et al.'s (2000) model of executive functions (the two other are working memory and inhibition). Cognitive flexibility refers to task or attention switching, that is, the ability to shift attention between tasks, operations, or mental sets in a flexible way. There is evidence that cognitive flexibility contributes to reading comprehension because this task requires the coordination of multiple attention-control processes. That is, readers must pay attention to text features at phonological, semantic, and syntactic levels simultaneously. Besides, readers must use cognitive and metacognitive strategies to sustain their process of meaning construction (Butterfuss & Kendeou, 2017). For example, if readers are not able to shift attention from word-level processing, their text understanding may be impaired (Cartwright, 2006; Cartwright et al., 2017) and they may perceive high cognitive load in trying to activate multiple processes simultaneously while reading (Chen et al., 2023). Moreover, when their cognitive flexibility is low, readers typically have difficulty shifting from the cognitive to the metacognitive level for monitoring their ongoing understanding of text, which is essential for accurate calibration (Israel, 2008).

In considering the role of these relevant individual differences, we tried to ensure that any possible effects of the manipulation of the two independent variables −multitasking and disfluency− were not due to such reader characteristics.

2. Method

2.1. Participants

We initially recruited 228 participants, but data regarding 20 students were excluded due to incomplete sessions (7) and incomplete tasks (13). The final sample was composed of 208 students (F = 72.04, M = 27.49%, Non-binary = 0.47%; M_{age} = 23.1, SD_{age} = 2.86) attending a large university in northern Italy. Of these students, 32.70% had attained a bachelor's degree, while 67.30% were enrolled in a master degree program. Approximately 99% of the students were native-born Italians with Italian as their primary language, and 1% were bilingual. The research project was approved by the Institutional Review Board and the study was conducted in accordance with the Declaration of Helsinki. Before the data collection, written informed consent was collected from all students, who participated for extra course credit.

To determine the minimum sample size required when manipulating the two independent variables and also considering the covariates, we performed an a priori power analysis using G*power (Faul et al., 2007), which was based on $\alpha = .05$, 1 β = 0.80, and an estimated medium effect size (f = 0.25). The statistical test selected for power analysis using G*Power was ANCOVA, with the following settings: numerator degree of freedom = 3, number of groups = 4, number of covariates = 4. The required sample size was 179 and, therefore, our number of participants was appropriate.

2.2. Experimental design

To address our research questions, we used a 2 x 2 between-subjects design for manipulating the multitasking (no vs. yes) and text fluency (fluent vs. disfluent) variables. Participants were randomly assigned to one of four conditions: multitasking fluent condition (n = 41), multitasking disfluent condition (n = 54), non-multitasking fluent condition (n = 57), and non-multitasking disfluent condition (n = 56). Differences in number of participants across the four conditions resulted from the exclusion of participants who did not complete all sessions and tasks. In the multitasking conditions, students were instructed to read the texts and respond to WhatsApp-like messages appearing on their screen while reading the texts.

2.3. Materials

2.3.1. Texts

Two informational texts addressing the controversial topic of sun exposure and health were used for this study. One of texts presented conflicting viewpoints concerning sun exposure's effects on mental health, and the other presented conflicting perspectives on its effects on physical health. The two texts were adapted versions of documents used in prior research on multiple document comprehension (Delgado et al., 2020; Haverkamp et al., 2024; Stang Lund et al., 2019). The text about mental health consisted of 1385 words, and the one about physical health consisted of 1391 words, making scrolling necessary in order to read the entire text. Readability was computed using the Gulpease index (Lucisano, 1993). The higher the score on the index (max 100 = very easy), the easier the text. The scores for the two texts were 46 and 52, respectively, indicating that both required some cognitive effort to be fully understood.

At the beginning of each text, information about the source was presented, including the author's name, credentials, and affiliation, in addition to publication date and venue. Each text was structured in two main parts, with each part divided into four paragraphs. Regarding sun exposure and mental health, the first part of the text presented and elaborated the perspective that a lack of sun exposure may lead to depression, both describing the underlying mechanisms and discussing the specific type of depression it might lead to, that is, seasonal affective disorder. The second part of this text introduced and elaborated the perspective that a lack of sunlight may lead to troubles sleeping but not depression, presenting evidence refuting the theory associating a lack of sunlight with depression.

Concerning sun exposure and physical health, the first part of the text presented and elaborated the perspective that sun exposure can be dangerous due to its potential to cause skin cancer, describing both the underlying mechanism and specifying the types of skin cancer that may result. Conversely, the second part of this text introduced and elaborated the perspective that sun exposure can be beneficial because it may offer protection against various types of cancer through the production of vitamin D, elucidating the underlying mechanism and describing types of illnesses that vitamin D may protect against.

The two texts were formatted using the same general settings, that is, single line spacing with a font size of 14. To manipulate the level of fluency, the font type in the fluent (easy-to-read) condition was Arial, whereas in the disfluent (harder-to-read) condition, the font type was Haettenschweiler on a 60% gray scale, adopting a setting used in previous educational research (Eitel & Kühl, 2016). Participants read the two texts in a counterbalanced order on a laptop equipped with a screen with a maximum resolution of 1920 x 1080 pixels. A fixed time of 10 min was given to read each text.

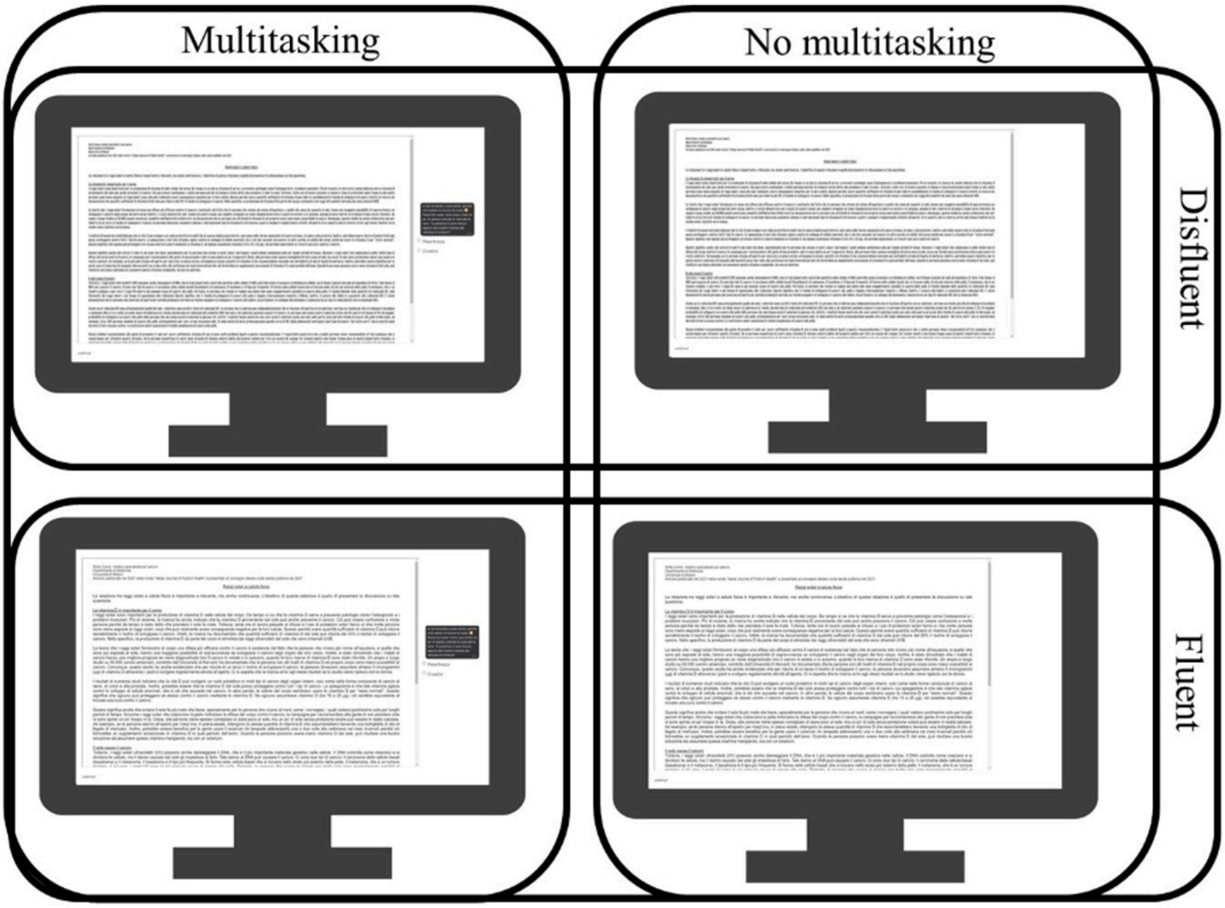

Fig. 1. Examples of Text presentation in the four experimental conditions.

2.3.2. Social-media messages

In the multitasking condition, seven messages appeared on the screen at random intervals (same randomness for all participants). To reduce the predictability of messages, we varied the length of the intervals such that the time between the messages varied between 35 and 80 s. Moreover, the presentation modality of the messages was written or auditory, with the modality varying in a counter-balanced order across the texts. All the messages resembled WhatsApp messages and each of them asked a question. Participants were told in advance that they might receive messages while reading. They were asked to consider these messages and respond to them by selecting one of two available options (see Fig. 1). The messages covered various everyday scenarios, such as an invitation to a party and selecting what to bring there, watching a movie at the cinema with show time options, planning a mountain trip with traveling choices, selecting the size of a sweater for a birthday gift, and deciding between fresh bread or croutons for dinner. Other messages included confirming attendees for a dinner reservation, deciding on a vacation destination, selecting a gym activity, adopting a puppy for company, picking an assignment due date, advising on car trouble, and recommending a restaurant cuisine. A sample message is: “Hey! This week the movie we talked about the other day is finally in the cinema. I suggest going there Wednesday evening because they offer student discounts. There are two show times, 7:30 p.m. or 9:00 p.m. Which one do you prefer?”. The response options were: a) 7:30 p.m., b) 9:00 p.m. Another example is: “I need your help!! I want to adopt a puppy so that my sister still has company in her new apartment. Her place is large but doesn’t have a yard. I’m undecided about a dog or a cat, what do you suggest?”. The response options were: a) a dog, b) a cat.

Of note is that the questions in the messages did not have a correct answer. Readers could choose one option according to their preference, which was recorded to ensure that the secondary task was carried out. The arrival of a message was signaled by a notification sound. All messages appeared on the right side of the screen, at mid-height, and remained on the screen for 20 sec before disappearing. All participants in the multitasking conditions received the same two sets of seven messages, one set for each text, counterbalanced with respect to text topic and presentation modality.

2.4. Dependent measures

In the following, we describe the dependent variables of cognitive load, integrated text understanding, and metacognitive calibration.

2.4.1. Cognitive load

Immediately after reading each text, participants self-reported their perception of cognitive load using a 5-item scale adapted from Klepsch et al. (2017). This scale measures both intrinsic and extraneous cognitive load. Participants expressed their agreement with each item on a 5-point scale (1 = not at all, 5 = very much; max = 25 points). Examples of items are: “*The way in which the text was displayed made it difficult to understand*” and “*During this task, it was exhausting to find the important information.*” The mean score was used as the measure of perceived cognitive load. As estimated by Mc Donald’s ω, the reliability was 0.82 for perceived cognitive load when reading in the multitasking conditions and 0.83 when reading in the non-multitasking conditions.

2.4.2. Integrated Text understanding

Participants’ integrated understanding was assessed using a brief essay. The instruction for both texts was: “*There are different perspectives on the relationship between sunlight exposure, mental health, and pathology. Now we ask you to write a text (no less than 10 lines) explaining the similarities and differences between these perspectives. Base your writing on what you just read and try to express yourself in the most clear and complete way possible, using your own words. You have a maximum of 15 min to complete the task*”. Participants’ answers were evaluated using a scoring rubric. Each essay was initially assessed based on the presentation of the two perspectives, using a scoring system ranging from 0 to 2. A score of 0 was assigned if only one perspective was presented or if both perspectives were mentioned but only outlined with basic elements (e.g., mentioning that sun exposure has both positive effects, such as increasing vitamin D levels, and negative effects, such as increasing the risk of skin cancer). A score of 1 was given if both perspectives were included but not fully developed (e.g., some additional information was provided regarding the effects of sun exposure). Finally, a score of 2 was awarded if both perspectives were not only presented but also thoroughly elaborated (e.g., by discussing the various factors that contribute to the relationship between sun exposure and skin cancer). In the next step, the integration of the two perspectives presented in each text was awarded 0–2 points (Haverkamp et al., 2024). Specifically, 0 points were given to an essay if the two perspectives were not compared, contrasted, or connected in any way; 1 point was given if the two perspective were compared, contrasted, or connected but not in elaborated way; and 2 points were awarded if the two perspectives were compared, contrasted, or connected in an elaborated way (see Supplementary Materials for examples of the scoring rubric). Lastly, the two scores (the representation of the two perspectives and the integration of the perspectives) were summed up as a measure of integrated understanding for each text, and the scores for the two texts were collapsed to serve as our dependent variable (maximum score = 8).

Under the guidance of the third and fourth authors, two independent raters (trained master students) scored approximately 25% of the responses together. The remaining responses were then scored independently. Regarding the text on physical health, interrater reliability (ICC) was 0.99 for representation of perspectives and 0.99 for integration; for the text on mental health, these reliabilities were 0.97 and 0.84.

2.4.3. Metacognitive calibration

Participants’ were asked “*How well did you understand the text that you have just read? By moving the cursor you can choose the number (from 0 to 100) that best reflects your understanding.*” Metacognitive calibration was computed as calibration bias by subtracting their self-evaluation of understanding from their actual performance to indicate whether they underestimated or overestimated their text understanding (Schraw, 2009). Values closer to zero indicated optimal calibration, whereas negative and positive values indicated underestimation and overestimation, respectively.

2.5. Control variables

To account for individual differences that could impact performance, we considered the following variables as control variables and potential moderators.

2.5.1. Prior knowledge

Participants' prior knowledge about the effects of sun exposure on health was assessed using 24 multiple-choice items with four response options. This measure was a translated and adapted version of a measure used in previous research (e.g., Haverkamp et al., 2024; Stang Lund et al., 2019). The items addressed issues regarding the impact of sun exposure on both physical and mental health aspects (e.g., skin cancer, vitamin D production, depression, and sleep quality). The score was the sum of correct responses (maximum score = 24). An example item is: "*Vitamin D is produced in the body only when (a) we exercise; (b) the body is exposed to microwave radiation; (c) the skin cells are irradiated by ultraviolet radiation; (d) we sleep*". The internal consistency reliability (Mc Donald's ω) was 0.61.

2.5.2. Reading comprehension skills

We assessed students' comprehension skills by adapting the Deep Cloze Test (Jensen & Elbro, 2022) for use with Italian adult readers. This test was created to measure readers' global inference making, that is, how well readers are able to understand and integrate information to form a coherent overall understanding of text content (Bråten et al., 2024). The test includes 34 cloze sentences embedded in short narrative paragraphs that are to be completed in 10 min. In the middle or at the end of each of the paragraphs, there is a cloze with four response options. To identify the correct options, readers must make global inferences regarding the contexts described in the paragraphs. The score was the number of correct answers (maximum score = 34 points). An example of items is: "*He was on his way to bed. He squeezed the tube, looked at himself in the mirror, and began to [dream, calculate, brush, write].*" As estimated by McDonald's ω, the reliability was 0.82.

2.5.3. Working memory

Participants' verbal working memory was measured using an Italian adaptation (Pazzaglia et al., 2000) of Daneman and Carpenter's (1980) Reading Span Test. The task consisted of 12 sets of sentences, with the number of sentences within the sets increasing progressively throughout the task, from a minimum of 2 to a maximum of 5 sentences. Participants completed three trials for each level of the task. Each sentence was presented visually on a screen and participants were asked to read it silently, click on the appropriate button to indicate whether the sentence was true or false, and remember its last word. At the end of each trial, participants wrote the last word of each sentence in the set following the correct presentation order. The final score was computed as the total number of last words recalled in the correct order (maximum score = 42 points). Split-half reliability for this task was $r = 0.83$.

2.5.4. Cognitive flexibility

Participants' cognitive flexibility was assessed using the Wisconsin Card Sorting Test (WCST), adapted from Greve et al. (2005). In each trial of this task, a response card is placed below four stimulus cards. The stimulus cards are defined by three dimensions: color (red, blue, yellow, green), form (circles, triangles, stars, crosses), and number (one, two, three, four). For each of the 64 trials, participants are instructed to match the response card to one of the four stimulus cards based on a specific sorting rule, such as color, number, or shape. For instance, a response card featuring three red circles could be matched based on color (red), form (circle), or number (three). The sorting rule, determining for which dimension the card needs to match, is not explicitly provided but should be discovered through a process of trial and error. After each response, participants receive feedback (i.e., 'correct' or 'incorrect'), aiding in the identification of the sorting rule. However, the sorting rule changes without warning after five consecutive correct responses, requiring participants to establish a new sorting rule for the next category. The total score was calculated based on the number of perseverative errors, reflecting how many times participants failed to adjust their sorting approach when the sorting rule changed, continuing to sort the cards according to the previous, no longer valid rule. A higher number of perseverative errors is indicative of lower cognitive flexibility. Split-half reliability for this task was $r = 0.84$.

2.6. Procedure

Data were collected by means of the platform Labvanced during two group sessions in a university IT room that were approximately one week apart. In the first session, participants created their identification code and completed a demographic questionnaire (age, gender, language, neurodevelopmental disorders, and course type and year). Students also completed the measures of prior knowledge, reading comprehension skills, verbal working memory, and cognitive flexibility. In the second session, participants were randomly assigned to one of the four conditions in the fully crossed multitasking (yes or not) x fluency (easier-to-read or harder-to-read) design. Specifically, in this session students read two texts (one about sunlight and physical health and one about sunlight and mental health). The topics were counterbalanced across participants. After reading the first text, participants watched a 5-min relaxing video about marine organisms. All participants were instructed to read each text carefully, as if it were a scientific article to be studied, but without taking notes. They were informed that the time limit was 10 min, after which they would be asked to write a brief essay without revisiting the text. In the multitasking condition only, participants were also instructed to read and respond to the messages.

After reading each text, participants reported their perception of cognitive load and self-evaluated their understanding. Then, they wrote the essay to explain important similarities and differences between the different views. Participants had a maximum of 15 min to write the essay.

2.7. Analytical approach

To answer each of the research questions, we used analyses of covariance (ANCOVA) with multitasking and fluency as independent variables and with scores for cognitive load, integrated text understanding, and calibration bias as the dependent variables. Prior knowledge, reading comprehension skills, working memory (WM), and cognitive flexibility (perseverance errors) were only included as control variables when they correlated with the dependent variable of interest (if not, analyses of variance (ANOVAs) were conducted).

3. Results

3.1. Preliminary analyses

Data were first tested for normal distribution. The measured variables were approximately normally distributed and, thus, suitable for parametric statistical analyses. Table 1 includes descriptive statistics and correlations for all variables for the entire sample.

The control variables of prior knowledge ($r = 0.243$, $p < .001$), reading comprehension ($r = 0.356$, $p < .001$), and working memory ($r = 0.269$, $p < .001$) were positively correlated with integrated understanding. Perseverative errors in the cognitive flexibility task ($r = -0.156$ $p = < 0.01$) and metacognitive calibration ($r = -0.213$, $p < .01$) were negatively correlated with integrated understanding. In contrast, cognitive load was not correlated with any of the control variables.

To ensure that individual characteristics were not different across the experimental conditions, we performed an analysis of variance (ANOVA) with the four conditions as independent variables and the control variables as dependent variables. The analysis did not show statistically significant differences for any of the variables, with $F(3, 204) = 2.31$, $p = .078$, $\eta^2 = 0.033$ for working memory and $Fs < 1$ for prior knowledge ($\eta^2 = 0.007$), reading comprehension ($\eta^2 = 0.001$), and perseverative errors in the cognitive flexibility task ($\eta^2 = 0.014$) (see Table 2 for descriptive information).

3.2. Research question 1: effects of multitasking and Text fluency on cognitive load

We conducted a 2 x 2 factorial analysis of variance (ANOVA) with multitasking (i.e., multitasking vs. non-multitasking) and text fluency (i.e., fluent vs. disfluent) as the independent variables and the cognitive load score as the dependent variable. None of the covariates was included because they did not correlate with the dependent variable. Neither the main effect of multitasking, $F(1, 204) = 1.50$, $p = .222$, $\eta_p^2 = .007$), nor the main effect of fluency, $F(1, 204) = 2.27$, $p = .134$, $\eta_p^2 = .01$), or the interaction between multitasking and text fluency, $F(1, 204) = 0.46$, $p = .499$, $\eta_p^2 = .002$, were statistically significant (see Table 2 for descriptive information). Participants' subjective perception of mental effort was essentially the same across conditions.

Table 1
Descriptive statistics and correlations for the entire sample (N = 208).

	1	2	3	4	5	6	7
1. Prior knowledge	–						
2. Reading comprehension	0.215[b]	–					
3. Working memory	0.226[b]	0.416[c]	–				
4. Cognitive flexibility	−0.132	−0.250[c]	−0.321[c]	–			
5. Cognitive load	0.017	−0.054	0.004	−0.037	–		
6. Integrated understanding	0.243[c]	0.356[c]	0.269[c]	−0.16[a]	−0.103	–	
7. Metacognitive calibration bias	−0.065	−0.032	−0.056	−0.035	−0.342[b]	−0.213[b]	
M	16.71	25.23	35.17	5.74	11.96	4.55	57.93
SD	2.56	4.08	5.89	6.80	2.86	1.63	23.31
Skewness	−0.31	−0.85	−1.15	2.44	0.20	0.08	−0.10

[a] $p < .05$.
[b] $p < .01$.
[c] $p < .001$.

Table 2
Descriptive statistics for the measured variables by experimental condition (N = 208).

	Multitasking				Non-multitasking			
	Fluency		Disfluency		Fluency		Disfluency	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Prior knowledge	16.85	(2.30)	25.11	(4.24)	16.49	(2.76)	16.57	(2.54)
Reading comprehension	25.22	(4.00)	25.11	(4.24)	25.46	(3.86)	25.13	(4.29)
Working memory	35.80	(5.22)	34.15	(6.38)	34.26	(6.08)	36.61	(5.44)
Cognitive flexibility	5.41	(8.18)	6.41	(6.02)	6.46	(8.22)	4.59	(4.39)
Cognitive load	12.05	(2.64)	12.38	(3.07)	11.29	(2.50)	12.16	(3.10)
Integrated understanding	4.29	(1.66)	4.28	(1.41)	4.66	(1.68)	4.89	(1.71)
Metacognitive calibration	52.01	(23.16)	58.87	(24.06)	59.58	(22.01)	59.68	(23.91)

3.3. Research question 2: effects of multitasking and Text fluency on integrated understanding

We next conducted a 2 x 2 factorial analysis of covariance (ANCOVA) with multitasking (i.e., multitasking vs. non-multitasking) and text fluency (i.e., fluent vs. disfluent) as the independent variables and integrated text understanding as the dependent variable. Working memory, perseverative errors in the cognitive flexibility task, reading comprehension skills, and prior knowledge were entered as covariates. The assumptions for conducting the ANCOVA were met. The main effect of multitasking on integrated understanding was statistically significant, $F(1, 200) = 5.86$, $p = .016$, $\eta_p^2 = 0.028$). The effect size ($d = 0.34$) was relatively small yet untrivial and similar to that reported in the meta-analysis by Clinton-Lisell (2021).

However, neither the main effect of text fluency, $F(1, 200) = 0.38$, $p = .537$ $\eta_p^2 = .002$, nor the interaction between multitasking and text fluency, $F(1, 200) = 0.64$, $p = .424$, $\eta_p^2 = .003$, were statistically significant. The covariates of reading comprehension, $F(1, 200) = 13.61$, $p < .001$, $\eta_p^2 = 0.062$, and prior knowledge, $F(1, 200) = 6.63$, $p = .011$, $\eta_p^2 = 0.032$, uniquely adjusted participants' integrated understanding scores, whereas working memory, $F(1, 200) = 2.41$, $p = .122$, $\eta_p^2 = .012$, and cognitive flexibility in terms of perseverative errors, $F(1, 200) = 0.25$, $p = .612$, $\eta_p^2 = .001$, did not uniquely contribute to the outcome.

3.4. Research question 3: effects of multitasking and Text fluency on metacognitive calibration

We conducted a univariate analysis of variance (ANOVA) with multitasking (i.e., multitasking vs. non-multitasking) and text fluency (i.e., fluent vs. disfluent) as the independent variables and judgment of comprehension as the dependent variable. None of the covariates was included because they did not correlate with the dependent variable. The effects of multitasking, $F(1, 204) = 1.65$, $p = .200$, $\eta_p^2 = .008$, text fluency, $F(1, 204) = 1.14$, $p = .286$, $\eta_p^2 = .006$, and their interaction, $F(1, 204) = 1.07$, $p = .301$, $\eta_p^2 = .005$, were not statistically significant. Participants did not perceive the impact of either multitasking or text fluency on the accuracy of their judgment which, nevertheless, revealed a considerable calibration bias in the form of an overestimation of their understanding.

4. Discussion

This study is unique in investigating the effects of both multitasking and disfluency on cognitive load, integrative understanding of dual-positional texts, and metacognitive calibration. Based on the mixed results in the extant literature, we formulated different working hypotheses for the guiding research questions. We were particularly interested in possible interactive effects of the two independent variables. The presentation of perceptually disfluent texts could be a beneficial condition that counteract a tendency toward superficial processing when reading digital texts (Annisette & Lafreniere, 2017), especially in a multitasking context in which resources are detracted from a primary demanding reading task in order to process a secondary incompatible task such as responding to social media messages. According to disfluency theory (e.g., Alter et al., 2007; Diemand-Yauman et al., 2011), perceptual difficulty when reading may signal a need for deeper, elaborative processing, with benefits for reading outcomes.

The first research question asked whether multitasking and disfluency would impact the subjective perception of cognitive load. *Hypothesis 1a* was confirmed as none of the manipulated variables had statistically significant effects, nor did their interaction. Students' subjective perception of mental load did not vary according to the reading condition. This finding aligns with the investigations that did not indicate a perception of higher cognitive load associated with multitasking when reading short social media messages (Ronconi et al., 2024), or associated with disfluency when learning from multimedia materials (Eitel et al., 2016; exp. 2, 3, and 4).

The second research question asked whether multitasking and disfluency would impact the integrated understanding of dual-positional texts. The results partially confirmed *hypothesis 2b*. Students who responded to social media messages while reading obtained lower scores for comparing, contrasting, or connecting different perspectives on the issue of sun exposure and health. The negative impact of multitasking during reading confirms previous investigations that used single (e.g., Lin et al., 2011) or multiple texts (Haverkamp et al., 2024), as well as the meta-analysis by Clinton-Lisell (2021). The meta-analysis indicated an overall detrimental effect of multitasking on the basis of twenty studies involving adult readers of expository text, in particular when the reading time was established by the experimenter, such as in the current study.

With reference to the theory of threated cognition (Salvucci & Taatgen, 2011), the lower performance of multitasking readers can be explained in terms of processing resources that were detracted from the primary demanding task, with reading and responding to social media messages resulting in less relevant resources available to understand the dual-positional texts. According to this theory, cognitive activities with incompatible goals that draw on the same resources cannot be effectively and efficiently carried out in parallel, only serially. And, although multitasking was intermittent, with students reading the text in-between the social media messages, students may still have been disturbed by the incompatible secondary task when returning to their primary task (Strayer et al., 2022).

For disfluency, *hypothesis 2b* was not confirmed, however. Thus, the perceptual difficulty of reading the texts did not seem to play a role in integrated understanding of the content, confirming *hypothesis 2a*. This is consistent with previous educational studies that have failed to demonstrate better understanding when reading harder-to-read texts than when reading easy-to-read texts (Eitel et al., 2014, exp. 2, 3, and 4; Eitel & Kühl, 2016).

Taken together, the findings regarding integrated understanding and perception of cognitive load indicate students in the multitasking condition performed less well although they did not perceive the cognitive load to be higher than did those who did not multitask. We can speculate that their subjective reports of cognitive load might have been inaccurate. Alternatively, they may have liked receiving and responding to social messages and therefore felt no additional load despite the fact that the intermittent secondary task actually interfered with their text understanding.

The third research question asked whether multitasking and disfluency would impact students' metacognitive calibration, that is, the ability to accurately self-evaluate their own understanding of the texts. Inaccuracy can lead to either underestimation or overestimation. *Hypothesis 3a* was confirmed because none of the independent variables had any effects on calibration bias. Overall, participants overestimated their meaning construction about sun exposure and health to the same extent regardless of whether they focused only on reading the two texts or combined this with responding to social messages, and also regardless of whether they read the texts in easy-to-read or in harder-to-read fonts. The lack of a disfluency effect also emerged in previous research, although that research mainly focused on memory for lists of words (Magreehan et al., 2016; Yue et al., 2013). The effects of multitasking during text reading on metacognitive calibration have received very little attention in the extant literature. Only one study focusing on habitual multitasking has suggested an association between multitasking and lower metacomprehension accuracy of text understanding (Romero et al., 2023), whereas other investigations based on reading word pairs have indicated a negative impact of multitasking (e.g., Guo et al., 2024). Undoubtedly, further research is needed on various outcomes when readers engage in a secondary, incompatible task during reading.

Table 3 summarizes the tested and confirmed hypotheses. For cognitive load and metacognitive calibration, *hypothesis 1a* and *hypothesis 3a* were confirmed, respectively, as no effects due to on-screen multitasking and disfluency emerged. For integrated understanding, *hypothesis 2b* was confirmed as multitaskers showed lower understanding of the dual positional text than no-multitaskers.

Two overall findings need to be highlighted. The first is the lack of a disfluency effect on all the measured outcomes. This is not really surprising in light of some prior research, in particular regarding the learning of complex materials (e.g., Kühl & Eitel, 2016). A possibility is that the disfluent texts were not sufficiently hard to read, which means that the perceptual difficulty may not have been at a 'desirable' level for our participants (Bjork, 2013). This possibility is supported by the fact that participants did not perceive the cognitive load to be higher in the text disfluency conditions. Another possibility is that disfluency may play a role in some contexts and for students with some characteristics, for example with respect to working memory (Bjork & Yue, 2016; Dunlosky & Mueller, 2016). Lehmann et al. (2016) indicated that only in the disfluency condition the higher the working memory, the better the text comprehension.

The second finding that needs to be emphasized is the lack of any interactive effects of multitasking and disfluency. This suggests that in the context of multitasking during reading, disfluency does not contribute to the outcomes we measured. In contrast, Halin (2016) and Halin et al. (2014) found that disfluency interacted with the reading condition, supporting participants when reading with a noisy background. In our study, neither an additive nor a compensatory effect emerged. That is, text disfluency did not increase the perception of cognitive load, lower integrated understanding, or increase calibration bias; nor did it mitigate the negative impact of multitasking by promoting deeper elaborative processing with positive consequences for understanding and metacognitive calibration of understanding. Thus, the current study cannot recommend using disfluency as a simple intervention to increase productive processing of learning materials and achieve better meaning construction from texts. More research is needed to understand under what conditions a difficulty is perceived as such and, more importantly, when it is not merely a difficulty but a desirable one (Bjork & Yue, 2016).

Table 3
Tested and Confirmed Hypotheses.

Hypothesis 1. Multitasking and disfluency on cognitive load	
H 1a. No effect on cognitive load	H 1b
✓	x
Hypothesis 2. Multitasking and disfluency on integrated understanding	
H 2a	H 2b Independent effect of multitasking on integrated understanding
x	✓
Hypothesis 3 Multitasking and disfluency on metacognitive calibration	
H 3a No effect on metacognitive calibration	H 3b
✓	x

4.1. Practical implications

The findings of this study highlight the negative impact of media multitasking while reading longer and relatively complex texts for academic purposes. As students constantly use digital devices that are permanently connected to the Internet, it seems particularly relevant to make them aware of the negative consequences that likely follow from performing a secondary task while reading academic texts. We used simple social messages that did not lead to perceptions of cognitive overload. Nevertheless, participants' integrated understanding was poorer in the multitasking condition. However, at the same time, participants did not perceive a decrement in their own performance according to our measure of metacognitive calibration. Taken together, these findings support the notion that students need to become aware that even briefly responding to short social messages while listening to a lecture or reading learning materials may have cognitive costs in terms of content processing and comprehension performance. They should also be supported in reflecting on how they could resist on-screen distractions and exert top-down attentional control. Of great concern is that the multitasking behavior of a single student even may be detrimental to the learning of other students (Sana et al., 2013).

Further, our findings indicate that a subtle manipulation of perceptual disfluency is not an effective way to sustain text understanding in the context of multitasking. It seems that the supposed metacognitive experience of increased difficulty while completing the reading task did not occur, thus limiting the potential effect of metacognitive monitoring and control processes. Presumably, students did not engage in more effortful processing when reading the disfluent text as the difficulty was not at a desirable level. Although educational interventions for supporting understanding of complex issues cannot rely on perceptual difficulty (Kühl & Eitel, 2016), relevant difficulty can be related to more inherent components of reading comprehension, for example the generation of information that is critical to construct meaning from text.

4.2. Limitations and directions for future research

Some limitations should be taken into account when interpreting the results of the present study and planning future research in this area. First, we set a fixed time for reading the expository texts, mainly based on findings from prior research comparing digital and print-based reading (Clinton, 2019; Delgado et al., 2018) and prior research on multitasking during reading (Clinton-Lisell, 2021). However, when investigating text disfluency, variation in time use may also indicate more or less difficult text reading. That is, if time use does not increase when reading disfluent texts, this may indicate that the perceptual difficulty is not sufficient to slow down text processing. In future research, eye-tracking methodology could be a more suitable way to investigate the process of reading in the context of multitasking (Ronconi et al., 2024) because it can reveal patterns of visual behavior during intermittent multitasking with easy-to-read and harder-to-read texts. For instance, this methodology may be used to examine continued interference from the secondary task after readers have responded to a social media message and returned to the primary task (Strayer et al., 2022).

Second, we did not focus on possible interactions of multitasking or disfluency with individual differences, which were only considered as control variables to ensure that participants in the four conditions were comparable with respect to individual characteristics that could contribute to the outcomes. However, habitual multitasking, working memory, or cognitive flexibility, for instance, might moderate the outcomes of multitasking (Murphy & Creux, 2021) or disfluency (Lehmann et al., 2016). Third, we did not take participants' affective or motivational characteristics into account. One such characteristic is topic interest (Renninger & Hidi, 2016), which is a resource for single (e.g., Boscolo & Mason, 2003) and multiple text comprehension (e.g., Strømsø & Bråten, 2009). When students are more interested in the content, that is, assign greater importance to a topic and are disposed to know more about it, their engagement in the reading task gets deeper (Schiefele, 1996). Thus, they also might be better able to manage multitasking without compromising their text comprehension. Relevant in this regard, there is evidence of shorter reaction times to occasionally appearing probes in dual-task studies when participants are reading texts perceived as more interesting (McDaniel et al., 2000). There is also evidence, however, that topic interest does not moderate the effects of interruptions during a video presentation (Conard & Marsh, 2014). In any case, it seems worthwhile investigating not only cognitive but also motivational individual differences that might play a moderating role in multitasking contexts. Hopefully, with more complex designs, future studies can shed further light on the interaction between text, reader, and context.

Fourth, in the multitasking condition we used simple social media messages asking questions that did not have a correct answer, thus we could not assess the accuracy of participants' responses. In future research, it would be relevant to include messages that imply different levels of cognitive load and ask questions requiring responses that could be scored for accuracy. Examining response accuracy could provide additional insights into how multitasking affects not just the act of responding but also the quality of the responses. Thus, including a measure of response accuracy could enhance our understanding of the impact of multitasking on cognitive load, text understanding, and self-evaluation of understanding.

Fifth, the ecological validity of the study can be improved in future research. We strived to simulate an authentic context of multitasking by using a secondary task involving reading and responding to social media messages. Further, we used disfluent texts that were only slightly harder to read, similar to some authentic documents (e.g., old scanned articles in pdf format). Still, when reading a text, participants could not go back to the previous page in the way it may happen in a natural reading condition. Future investigations could also design more authentic conditions by using longer and more demanding expository texts for the primary reading task.

4.3. Conclusions

Notwithstanding such limitations, this study brings together two separate lines of research −multitasking and text disfluency− and thus represents a step forward in educational research. We examined the impact of reading learning materials that could be considered perceptually harder to read in a context where the performance of the primary task was intermittently disturbed by the performance of a secondary incompatible task.

From a theoretical point of view, the study provides further evidence for a negative effect of multitasking on text understanding. At the same time, no evidence for the impact of perceptual disfluency when reading complex materials was found, even in a context of multitasking where the need for deeper, elaborative processing seemed crucial.

From a practical point of view, the study suggests that slight perceptual text disfluency is not influential *per se* or in combination with multitasking. Thus, using perceptual cues with the potential to increase effortful processing of demanding text content does not seem to be sufficient to counteract or mitigate negative effects of multitasking. Other interventions should be examined in connection with multitasking behavior. That said, a systematic review by Parry and le Roux (2019) was not particularly encouraging in this regard, as it did not demonstrate any effects of three different categories of intervention (i.e., awareness, restrictions, and mindfulness) on attention control. Nevertheless, educational researchers should continue exploring ways of helping students to use media technologies when completing academic tasks without negative interference from incompatible, non-academic tasks.

CRediT authorship contribution statement

Lucia Mason: Writing – original draft, Supervision, Methodology, Conceptualization. **Barbara Carretti:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Angelica Ronconi:** Writing – original draft, Software, Investigation, Data curation. **Eleonora Pizzigallo:** Writing – original draft, Investigation, Data curation. **Ymkje E. Haverkamp:** Resources, Methodology. **Ivar Bråten:** Writing – review & editing, Methodology.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2024.105172.

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